

**PRELIMINARY DESIGN OF METHANOL PLANT  
FROM COAL WITH GASIFICATION PROCESS  
CAPACITY OF 150,000 TONS/ YEAR**



**FINAL PROCET**

Asked to Meet Requirements Achieved Bachelor Degree in Strata 1 Engineering at Chemical Engineering Department Faculty of Engineering Universitas Muhammadiyah Surakarta

**Arranged by:**

**AISYAH ITSNAINI SHOLICHAH**

**D500122001**

**Supervisor:**

**1. Kusmiyati, S.T.,M.T., Ph.D**

**2. M.Mujiburohman, S.T., M.T., Ph.D.**

**CHEMICAL ENGINEERING DEPARTMENT FACULTY OF ENGINEERING  
UNIVERSITAS MUHAMMADIYAH SURAKARTA**

**2017**

**APPROVAL**  
**DEPARTEMENT OF CHEMICAL ENGINEERING**  
**FACULTY OF ENGINEERING**  
**UNIVERSITAS MUHAMMADIYAH SURAKARTA**

Name : Aisyah Itsnaini S.  
NIM : D 500 122 001  
Tittle of Final Project : Preliminary Design of Methanol Plant from Coal  
With Gasification Process Capacity 150,000  
Tons/Year  
Supervisor : 1. Kusmiyati, S.T., M.T., Ph.D.  
2. M. Mujiburohman, S.T., M.T., Ph.D.

Surakarta, Februari 2018

Has been approved by,

Supervisor I



**Kusmiyati, S.T., M.T., Ph.D.**

NIK.683

Supervisor II



**M. Mujiburohman, S.T., M.T., Ph.D.**

NIK.794

Dean of Engineering



**Ir. Sri Sunarjono, M.T., Ph.D.**

NIK. 682

Chairman of Department  
Chemical Engineering



**RoisFatoni, S.T., M.Sc., Ph.D.**

NIK.892

**DEPARTEMENT OF CHEMICAL ENGINEERING**  
**FACULTY OF ENGINEERING**  
**UNIVERSITAS MUHAMMADIYAH SURAKARTA**

---

**STATEMENT OF AUTHENTICITY OF THE FINAL PROJECT**

Name : Aisyah Itsnaini S.  
NIM : D 500 122 001  
Tittle of Final Project : Preliminary Design of Methanol Plant from Coal  
With Gasification Process Capacity 150,000  
Tons/Year  
Supervisor : 1. Kusmiyati, S.T., M.T., Ph.D.  
2. M. Mujiburohman, S.T., M.T., Ph.D.

States that the results of the final project I make and submit are the work of my own, excepts from summaries I have all explained from the source. If in the future it can be proved that this final project, then I will be willing to accept sanction in accordance with the applicable regulations.

Surakarta, Februari 2018

The state,

College Student



**Aisyah Itsnaini S.**

D 500 122 001

## DEDICATION

Bismillahirrahmanirrahim

*I dedicate this work to:*

*My parents, Siswanto and Sri Yuniati. Thank you for your endless love and support me.*

*Many thanks for :*

*My sister, Istiqomah for believe, and support me. You're my vitamin.*

*My cute, best friends, and vitamins classmate Anggie F. Asokawati, Aisyah Hanifah, Delta Mutiara, Diah Ayu Anggraeni, Imala Septi Cahyani, Salam Nurdin Aridin, Yulira Kus Rendra. We through all things together. You're best gift in my college life. I hope we still keep contact each others. Please be happy and wish you all the best.*

*My partnert Anggie F. Asokawati who always believe, and support. Sorry for these years. I make so much mistakes, but thank you for always stay in my side, listen to me, and believe me. Wish you all the best.*

*My cute friends Listiani, and Faza Hadaina who always support and help me Thank you for you'r place and memorries. You're my besty too. I hope we still keep contact each others. Wish you all the best and be happy.*

*My chat buddies Sofia Rahmawati and Shinta Wulandari who always help and support me. Thank you for accommodating me. Wish you all the best.*

*My friends in chemical engineering UMS 2012, senior and junior, and friends in K.H. Mas Mansyur. Thank you for makes so much memorries with me and thanks for you're help and support me. I wish you all the best, and see you next time.*

*Lecturers and staffs in department chemical Engineering UMS 2012. Thank you so much for support, guidance and encouragment.*

*May Allah S.W.T bless us all.*

*Thank you so much and wish you all the best.*

## PREFACE



Alhamdulillahirobbil ‘alamin, praise is merely to Almighty Allah SWT for gracious mercy and blessing, so this final project has been completed.

This report is one of compulsory subjects to pass bachelor degree in Department of Chemical Engineering, Faculty of Engineering, Universitas Muhammadiyah Surakarta. In this opportunity author grateful to all those who helped in completing Final Project Report in particular to:

1. RoisFatoni, S.T., M.Sc., Ph.D as Chairman of Department Chemical Engineering, Faculty of Engineering, Universitas Muhammadiyah Surakarta
2. Kusmiyati, S.T., M.T., Ph.D as Supervisor I
3. M. Mujiburohman, S.T., M.T., Ph.D as Supervisor II
4. Lecturers in Chemical Engineering Department, Universitas Muhammadiyah Surakarta
5. Angie F. Asokawati as my partner in final project
6. Family and friends who have given endorsement and prayer
7. Everyone who has supported

Due to limitations in preparation of this report, author aware that this report might have some shortcomings. Therefore suggestion and constructive criticism to improve this report are welcome. Author wish this report will be useful for all those who concern.

Surakarta, 30 Januari 2018

Aisyah Itsnaini S.

## LIST OF CONTENTS

COVER .....	i
VALIDATION .....	ii
STATEMENT OF AUTHENTICITY OF THE FINAL PROJECT .....	iii
DEDICATION .....	iv
PREFACE .....	v
LIST OF CONTENTS .....	vi
LIST OF TABLES .....	xi
LIST OF FIGURES .....	xv
ABSTRACT.....	xvi
CHAPTER I INTRODUCTION .....	1
1.1. Background of factory establishment .....	1
1.2.Design capacity .....	3
1.2.1. Projection of methanol demand in the country .....	3
1.2.2. Available of Raw Materials .....	4
1.2.3. Capacity of Existing Methanol Plant .....	5
1.3. Factory Location Selection .....	5
1.3.1. Primary Factor.....	5
1.3.2. Secondary Factors .....	6
1.4. Review Library .....	6
1.4.1. Kinds of Processes .....	7
1.4.2. Product Uses .....	8
1.4.3. Physical and Chemical Properties .....	9
CHAPTER II PROCESS DESCRIPTION .....	13
2.1. Specification of Raw Materials and Products .....	13
2.1.1. Specification of Raw Materials.....	13
2.1.1.1. Specification of Coal.....	13
2.1.1.2. Spesification of Oxygen.....	13
2.1.1.3. Specification of Water .....	14
2.1.2. Specification of Product.....	14

2.1.2.1. Specification of Methanol.....	14
2.1.3. Specification of Additional Material.....	14
2.2. Concept Reaction .....	15
2.2.1. Basic Reaction.....	15
2.2.1.1. Coal Gasification .....	15
2.2.1.2. Water Gas Shift Reactor (WGSR)l.....	16
2.2.1.3. Fix Bed Reactor (FBR) / Methanol Synthesis .....	16
2.2.2. Mechanism Reaction.....	16
2.2.3. Operating Condition.....	16
2.2.3.1. Syngas Formation .....	16
2.2.3.2. Methanol Formation.....	17
2.2.4. Review of Thermodynamics .....	17
2.2.4.1. Gasification .....	18
2.2.4.2. Water Gas Shift Reactor (WGSR) .....	19
2.2.4.3. Methanol Synthesis (FBR).....	21
2.2.5. Review Kinetics .....	23
2.2.5.1. Gasifier.....	23
2.2.5.2. Water Gas Shift Reactor (WGSR) .....	24
2.2.5.3. FBR .....	24
2.3. Stages of Process .....	25
2.3.1. Raw Material Preparation Stage.....	26
2.3.2. The Process Stage .....	26
2.3.3. Purification of The Product Stage .....	26
2.4. Process Flow Diagram .....	27
2.4.1. Quantitative Diagram .....	27
2.4.2. Qualitative Diagram .....	29
2.5. Mass Balance and Heat Balance .....	30
2.5.1. Mass Balance .....	30
2.5.2. Heat Balance .....	35
2.6. Plant Layout and Equipment.....	46
2.6.1. Plant Layout .....	46

2.6.2. Equipment Layout .....	49
CHAPTER III EQUIPMENT SPESIFICATION .....	51
3.1. Main Equipment Specification .....	51
3.1.1. Reactor Gasifier .....	51
3.1.2. Reactor Water Gas Shift (WGSR) .....	51
3.1.3. Reactor Fix Bed (FBR) .....	52
3.1.4. Absorber 1 .....	53
3.1.5. Absorber 2 .....	54
3.1.6. Distillation Tower 1 .....	54
3.2. Specification Supporting Tools.....	55
3.2.1. Storage Tank of Methanol( F-101) .....	55
3.2.2. Bin of Coal ( F-102).....	55
3.2.3. Condensor Partial 1 .....	56
3.2.4. Condensor Partial 2 .....	56
3.2.5. Condensor Partial 3 .....	57
3.2.6. Compressor 1 .....	58
3.2.7. Expansion Valve .....	58
3.2.8. Reboiler.....	59
3.2.9. Accumulator.....	59
3.2.10. Heat Exchanger 1 .....	60
3.2.11. Heat Exchanger 2 .....	60
3.2.12. Heat Exchanger 3 .....	61
3.2.13. Heat Exchanger 4 .....	62
3.2.14. Heat Exchanger 5 .....	63
3.2.15. Heat Exchanger 6 .....	64
3.2.16. Heat Exchanger 7 .....	64
3.2.17. Pump 1 .....	65
3.2.18. Pump 2 .....	66
3.2.19. Pump 3 .....	66
3.2.20. Mixer.....	67
3.2.21. Membran .....	67



3.2.22. Filter .....	67
CHAPTER IV UTILITIES AND LABORATORY .....	69
4.1. Utility .....	69
4.1.1. Water Procurement Unit .....	69
4.1.2. Steam Procurement Unit .....	74
4.1.3. Electricity .....	76
4.1.4. Fuel Procurement Unit .....	79
4.1.5. Pressurized Air Procurement Unit .....	80
4.1.6. Dowtherm A Procurement Unit .....	80
4.2. Laboratory .....	80
4.3. Waste Unit .....	81
4.3.1. Waste of Utility .....	81
4.3.2. Waste of Process .....	82
4.3.3. Waste Treatment .....	82
4.4. Health and safety work .....	82
CHAPTER V MANAGEMENT .....	92
5.1. Form of Company .....	92
5.2. Organizational Structure .....	92
5.3. Duties and Authorities .....	94
5.4. Research and Development .....	96
5.5. Working Hours Allocation .....	96
5.6. Status of Employees and Wages System .....	98
5.7. Classification of Position .....	99
5.8. Employee's Social Welfare .....	101
5.9. Production Management .....	101
CHAPTER VI ECONOMIC ANALYSIS .....	104
6.1. Equipments' price Approximation .....	108
6.2. Result Calculation .....	109
6.2.1. Total Capital Investment .....	109
6.2.2. Total Manufacturing Cost .....	111
6.2.3. Total Production Cost .....	112

6.2.4. Profit in Production .....	112
6.3. Feasibility Analysis .....	112
6.3.1. Percent Return of Investment (%ROI) .....	112
6.3.2. Pay Out Time (POT) .....	113
6.3.3. Break-even Point (BEP) .....	113
6.3.4. Shutdown Point (SDP) .....	114
6.3.5. Discounted Cash Flow (DCF) .....	114
CHAPTER VII CONCLUSION .....	117
BIBLIOGRAPHY .....	118
ATTACHMENT	

## LIST OF TABLE

Table 1.2.1 Data Import of Methanol in Indonesia.....	3
Table 1.4.1 Group of Coal based oh Color Content .....	7
Table 2.1.1 Spesification of Catalyst .....	15
Table 2.2.1 The value of $\Delta H^\circ_f$ in Gasifier.....	18
Table 2.2.2 The value of $\Delta G^\circ_f$ in Gasifirer .....	18
Table 2.2.3 The value of $\Delta H^\circ_f$ in WGSR .....	19
Table 2.2.4 The value of $\Delta G^\circ_f$ in WGSR .....	20
Table 2.2.5 The value of $\Delta H^\circ_f$ in FBR .....	21
Table 2.2.6 The value of $\Delta G^\circ_f$ in FBR .....	22
Table 2.2.7 The Value of each k .....	25
Table 2.5.1 Mass Balance in Mixer .....	30
Table 2.5.2 Mass Balance in Air Processing .....	31
Table 2.5.3 Mass Balance in Gasifier (R-01).....	31
Table 2.5.4 Mass Balance in Absorber 1 (D-201) .....	31
Table 2.5.5 Mass Balance in WGSR (R-102).....	32
Table 2.5.6 Mass Balance in Condensor Partial 1 (E-311).....	32
Table 2.5.7 Mass Balance in FBR (R-103).....	33
Table 2.5.8 Mass Balance in Absorber 2 (D-202) .....	33
Table 2.5.11 Mass Balance in Distillation Tower (D-211).....	34
Table 2.5.12.1 Mass Balance of Recycle .....	34
Table 2.5.12.2 Total Mass Balance.....	34
Table 2.5.13.1 Heat Balance Input Mixer.....	35
Table 2.5.13.2 Heat Balance Output Mixer .....	35
Table 2.5.13.3 Heat Balance .....	35
Table 2.5.14.1 Heat Balance Input Gasifier.....	35
Table 2.5.14.2 Heat Balance Output Gasifier .....	36
Table 2.5.14.3 Heat Balance .....	36
Table 2.5.15.1 Heat Balance Input Heat Exchanger 1 (E-301).....	36
Table 2.5.15.2 Heat Balance Output Heat Exchanger 1 (E-301).....	36

Table 2.5.15.3 Heat Balance .....	37
Table 2.5.16.1 Heat Balance Input Heat Exchanger 2 (E-302).....	37
Table 2.5.16.2 Heat Balance Output Heat Exchanger 2 (E-302).....	37
Table 2.5.16.3 Heat Balance .....	37
Table 2.5.17.1 Heat Input Balance Absorber 1 (D-201).....	38
Table 2.5.17.2 Heat Output Balance Absorber 1 (D-201) .....	38
Table 2.5.17.3 Heat Balance .....	38
Table 2.5.18.1 Heat Balance Input WGSR (R-102) .....	38
Table 2.5.18.2 Heat Balance Output WGSR (R-102).....	38
Table 2.5.18.3 Heat Balance .....	39
Table 2.5.19.1 Heat Balance Input Heat Exchanger 3 (E-303).....	39
Table 2.5.19.2 Heat Balance Output Heat Exchanger 3 (E-303).....	39
Table 2.5.19.3 Heat Balance .....	39
Table 2.5.20.1 Heat Balance Input Heat Exchanger 4 (E-304).....	39
Table 2.5.20.2 Heat Balance Output Heat Exchanger 4 (E-304).....	40
Table 2.5.20.3 Heat Balance .....	40
Table 2.5.21.1 Heat Balance Input Condensor Partial 1 (E-311) .....	40
Table 2.5.21.2 Heat Balance Output Condensor Partial 1 (E-311).....	40
Table 2.5.21.3 Heat Balance .....	41
Table 2.5.22.1 Heat Balance Input Heat Exchanger 5 (E-305).....	41
Table 2.5.22.2 Heat Balance Output Heat Exchanger 5 (E-305).....	41
Table 2.5.22.3 Heat Balance .....	41
Table 2.5.23.1 Heat Balance Input FBR (R-103) .....	41
Table 2.5.23.2 Heat Balance Output FBR (R-103).....	42
Table 2.5.23.3 Heat Balance .....	42
Table 2.5.24.1 Heat Balance Input Heat Exchanger 6 (E-306).....	42
Table 2.5.24.2 Heat Balance Output Heat Exchanger 6 (E-306).....	42
Table 2.5.24.3 Heat Balance .....	42
Table 2.5.25.1 Heat Balance Input Absorber 2 (D-202).....	43
Table 2.5.25.2 Heat Balance Output Absorber 2 (D-202) .....	43
Table 2.5.25.3 Heat Balance .....	43

Table 2.5.26.1 Heat Balance Input Condensor Partial 2 (E-312) .....	43
Table 2.5.26.2 Heat Balance Output Condensor Partial 2 (E-312).....	43
Table 2.5.26.3 Heat Balance .....	43
Table 2.5.27.1 Heat Balance Input Expansion Valve (G-201) .....	44
Table 2.5.27.2 Heat Balance Output Expansion Valve (G-201).....	44
Table 2.5.27.3 Heat Balance .....	44
Table 2.5.28.1 Heat Balance Input Heat Exchanger 7 (E-307).....	44
Table 2.5.28.2 Heat Balance Output Heat Exchanger 7 (E-307).....	44
Table 2.5.28.3 Heat Balance .....	44
Table 2.5.29 Heat Balance Input Distillation Tower (D-211) .....	45
Table 2.5.29.2 Heat Balance Output Distilat Distillation Tower (D-211).....	45
Table 2.5.29.3 Heat Balance Output Bottom Distillation Tower (D-211).....	45
Table 2.5.29.4 Heat Balance .....	45
Table 2.5.30.1 Heat Balance Input Condensor Partial 3 (E-313) .....	45
Table 2.5.30.2 Heat Balance Output Condensor Partial 3 (E-313).....	45
Table 2.5.30.3 Heat Balance .....	46
Table 4.1 Water Consumption for Process .....	73
Table 4.2 Water Consumption for Steam (Saturated Steam).....	73
Table 4.3 Water Consumption for Steam (Superheated Steam) .....	73
Table 4.4 Water Consumption for Domestic .....	73
Table 4.5 Electricity Consumption for Process Equipment.....	76
Table 4.6 Electricity Consumption for Utility .....	77
Table 4.7 Electricity Consumption for Lighting.....	78
Table 5.1 Work Schedules of Each Team .....	98
Table 5.6.2 Position classification, number of employees and salaries .....	99
Table 6.1 Cost Index data for 2002-2015 .....	108
Table 6.2 Fixed Capital Investment .....	110
Table 6.3 Working Capital Investment.....	110
Table 6.4 Direct Manufacturing Cost .....	111
Table 6.5 Indirect Manufacturing Cost.....	111
Table 6.6 Fixed Manufacturing Cost .....	111

Table 6.7 General Expense .....	112
Table 6.8 Fixed Cost .....	113
Table 6.9 Variable Cost .....	113
Table 6.10 Regulated Cost.....	114
Table 6.11 Summary of Economic .....	115

## LIST OF FIGURE

Figure 1.2.1 Word Consumption of Methanol .....	4
Figure 2.4.1 Flow Chart of Quantitative Methanol Plant .....	28
Figure 2.4.2 Flow Chart of Qualitative Methanol Plant .....	29
Figure 2.5.1 Plant Layout.....	48
Figure 2.6.2 Equipment Layout .....	50
Figure 6.1 Chemical Engineering Cost Index.....	108
Figure 6.2 Feasibility Analysis .....	116

## ABSTRACT

Methanol ( $\text{CH}_3$ ) is one of the hydrocarbon compounds of the alcohol group ( $\text{C}_n\text{H}_{2n+2}\text{O}$ ) with an alkyl hydroxyl group ( $-\text{OH}$ ). Derivative products of Methanol is acetic acid, MTBE, rubber, formaldehyde, etc. In Indonesia alone consumption of Methanol needs quite a lot, and raw material is very much. The raw material can take from Sumatera or Kalimantan. The plant is planned to establish in Sangatta area, East Kalimantan in 2025, because near with raw material, utility, transportation. The land area is  $3,800\text{m}^2$  and hire 159 employees.

The process of Methanol is in raw materials preparation stage, coal needed is 18,939.394 kg/hour, water 8,234.519 kg/hour, and oxygen 49,242.424 kg/hour. That will be heated in Gasifier Reactor with pressure 50 atm and temperature  $600^\circ\text{C}$ . Then input to Water Gas Shift Reactor (WGSR), at process stage will be react with water so  $\text{CO}_2$  content will increase using catalyst  $\text{CuO-ZnO-Al}_2\text{O}_3$  with pressure 49 atm and temperature  $409^\circ\text{C}$ . Then input to Fix Bed Reactor (FBR),  $\text{CO}$  and  $\text{CO}_2$  will be react with hydrogen to produce methanol and water content using catalyst  $\text{CuO-ZnO-Al}_2\text{O}_3$  at pressure 48 atm and temperature  $200^\circ\text{C}$ . At purification product stage, methanol and water are separated by distillation process. Methanol purification by distillation process to obtain methanol content is 99%. Supporting unit of the plant consist of water supply as much as 968,907 kg/hour which are processed from Mataram River, provision 21,038.298 kJ/hour of saturated steam, 34,970.805 kJ/hour of superheated steam, provision 998 kW of electricity, provision 236 liters/hour of diesel fuel, and provision 3,252 kg/hour of ammonia.

Amount of working capital is USD \$105,381,928 and Fix Capital Investment (FCI) is \$12,184,852.33. The economic analysis shows that Return On Investment (ROI) before tax is 59.93% and after tax is 45.24%. Pay Out Time (POT) before tax is 1.43 years and after tax is 1.9 years. Break event-point (BEP) is 47.74% capacity, Shut down point (SDP) is amounted at 39.57% capacity, and Discounted cash flow (DCF) is 30.28%. From data results of feasibility analysis can be concluded that the plant is profitable and feasible to be established.